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SHORT COMMUNICATION

Foraging of *Buthus occitanus* (Scorpiones: Buthidae) on shrub branches in an arid area of southeastern Spain

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Abstract. Little is known about the climbing habits of scorpions on plants, despite the interest in this behavior for understanding the connection between above- and below-ground food webs in deserts and to uncover the importance of prey availability and predator avoidance on foraging and habitat selection. Here we report on the foraging of *Buthus* cf. *occitanus* (Amoreux 1789) on shrub branches in an arid area in southeastern Spain. Black-light censuses were carried out within six 50 m × 4 m areas in one full and two new moon nights during September and October 2011. Shrub availability was estimated by counting shrubs in 50 m × 1 m areas within each census area. Results showed that nearly 40% of the scorpions, mostly small, 10–20-mm-long individuals, were found foraging on both inner and outer shrub branches up to 80 cm in height. The probability of finding a scorpion on a shrub was inversely related to scorpion size. Selectivity analysis showed that scorpions selected four shrub species, a result that may be related to prey size and availability. Foraging of *B. occitanus* on shrubs may be favored if this behavior not only allows access to shrub-inhabiting prey, but also reduces predation risk.

Keywords: Above-ground predation, shrub selectivity, size-related behavior

Small species and younger age classes of larger species of scorpions are known to forage both on the ground and on plants, climbing into shrubs and herbs (Polis 1990). Climbing of scorpions on shrubs is interesting for approaching two questions. First, this behavior is useful as a model system to understand how predators link soil and above ground food webs (Wardle et al. 2004; González-Megías et al. 2011), especially in arid ecosystems where scorpions are usually abundant. Second, despite the interest in this behavior for understanding the relative importance of resource availability and predation risk on foraging and habitat selection (Brown & O'Connell 2000), use of shrubs by scorpions has received little attention. Only a few papers have addressed this question studying a buthid species, *Centruroides vitattus* (Say 1863) (Brown & O'Connell 2000, McReynolds 2008). Here, we report the foraging of *Buthus* cf. *occitanus* (Amoreux 1789) on shrub branches in arid areas of the Guadix-Baza Basin (Granada province, southeastern Spain). The *B. occitanus* species complex (see Fet 2010; Rossi 2012) is comprised of large species showing flexibility in foraging behavior (Skutelsky 1995). The foraging of *Buthus occitanus* on branches of shrubs has been reported in the Negev Desert (Skutelsky 1996) and on small Mediterranean islands (Castilla & Pons 2007). In the Negev, Skutelsky (1996) found that 3% of the adult and 40% of the juvenile scorpions were observed on the outer branches of bushes. However, no other papers have described the climbing behavior of *Buthus occitanus* on shrubs, and no preeise information has been provided on 1) whether there are differences among size classes in climbing on shrubs, 2) selection for certain shrub species and whether it may be related to prey availability and 3) where the scorpions are located (height, inner/outer branches) on the shrubs.

Observations were made at Barranco del Espartal, a location in the arid Guadix-Baza Basin (Granada province, southeastern Spain). The site is an occasional watercourse with a gypsum loam substrate. The vegetation is an open shrubsteppe (58% bare soil, 41% shrub cover) dominated by *Artemisia* and *Salsola* shrubs, *Retama* bushes and *Stipa* tussock grasses (see Doblas et al. 2009 for a more detailed description of the study site). Sampling was carried out by exhaustive search using a black light in a total of six randomly selected 50 m × 4 m straight-line transects in plain sites around the dry riverbed. We surveyed scorpions on two new moon nights in September and one full moon night in October 2011 from 21:00 to 01:00. Each night we surveyed two different 50 m × 4 m transects, for a total of four transects in the two new moon nights and two transects in the full moon night. We measured the length (chelicerae to telson) of each scorpion (both on the ground and on shrubs) directly in the field. Scorpions were restrained in a thick, transparent plastic bag and their tails were straightened using a pair of forceps, measuring the total length of each individual with a small metal ruler. In addition, we recorded the type of shrub, the height of the scorpion and the scorpions position relative to the shrubs outside envelope (10 cm outer or > 10 cm inner branches). After measurement, each individual was released where it was found.

We used a Chi-square test to compare 1) the frequency distribution of scorpion size categories (>10–20 mm, >20–30 mm, >30–40 mm, >40–50 mm, > 50–60 mm, > 60 mm), and 2) the difference in frequency of scorpions on shrubs and on the ground between the two new moon nights and the full moon night. To test whether the presence of scorpions on shrubs or on the ground (binary categorical dependent variable) was correlated with scorpion size (continuous independent variable), we carried out a logistic regression (Quinn & Keough 2002) using the Statistica 7.1 package (StatSoft 2005). To analyze whether scorpions selected different types of shrubs, we counted the number of shrubs of each type in a 50 m × 1 m area in the center of each transect surveyed. Selectivity was quantified using the *Wi* Savage's index. This index is the ratio between the proportion of resources used and the proportion of available resources in the environment, with index values > 1 indicating preference and index values < 1 avoidance (Krebs 1999). Significance of selection was evaluated by the χ^2 test (Krebs 1999), with a posteriori correction of significance by the sequential Bonferroni procedure (Holm 1979).

In all, 148 scorpions ranging from 13 to 65 mm length were recorded during the surveys. Scorpion density was similar on the two new moon nights (23.0 ± 4.6 individuals/200 m^2, range 11–33 individuals/200 m^2) and the full moon night (22 and 35 individuals/200 m^2). Neither size frequency distribution ($\chi^2 = 5.44$, $P = 0.25$, $n = 148$) nor frequency of scorpions on shrubs and on the ground ($\chi^2 = 3.33$, $P = 0.07$, $n = 148$) showed differences between the two new

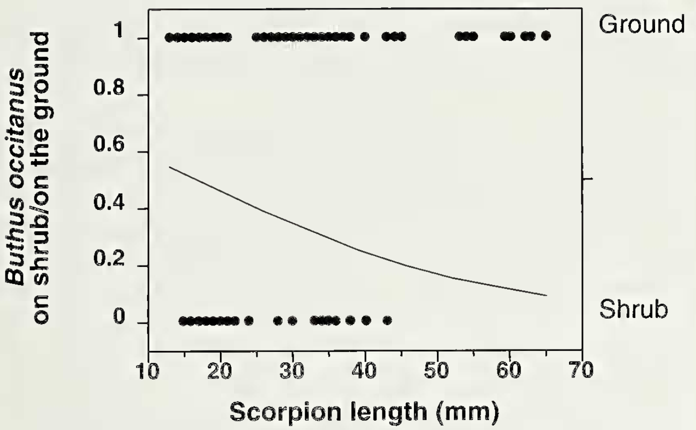

Figure 1.—Scatterplot of *Buthus* cf. *occitanus* observations on shrubs and on the ground in relation to body length, and predicted probability curve from the logistic regression model.

moon nights and the full moon night. Because data from the two new moon nights and the full moon night did not differ significantly, subsequent analyses were carried out pooling all surveys.

The population structure of *B.* cf. *occitanns* in the study site was dominated by 10–20 mm individuals, which comprised 54.7% of the total scorpions observed. In total, 39.9% of all individuals were found on shrub branches, although the proportion of individuals foraging on shrubs and on the ground varied with size: 46% of the smallest scorpions (10–20 mm length) occurred on shrubs, while 34% of the individuals measuring > 20 mm to 50 mm length and none of the individuals > 50 mm length were observed on shrubs. A logistic regression showed that the probability of finding a scorpion on a shrub significantly decreases as size increases, while the probability of finding a scorpion on the ground increases with body length (intercept: estimate = 0.615 ± 0.445, Wald χ^2 = 1.909, P = 0.167, df = 1; scorpion size: estimate = −0.043 ± 0.017, Wald χ^2 = 6.448, P = 0.011, df = 1) (Fig. 1).

Scorpions did not use shrubs randomly, but showed a significant selectivity for some shrub species (*Retama sphaerocarpa*, *Gypsophila struthium*, *Ononis tridentata* and *Lepidinm subulatnm*: Table 1). Scorpions occupied shrub branches 19.2 ± 4.5 cm high on average, most individuals (45%) occurring 10–20 cm high in the plants, but several individuals were above 50 cm and up to 80 cm. Individuals on shrubs were on both outer (53%) and inner (47%) branches of the plants. Scorpions remained still on the branches, usually facing down with pedipalps open (Fig. 2), attacking arthropods when they were close by (sit-and-wait foraging). During the surveys, we observed three scorpions successfully capturing prey (2 moths, 1 Cicadellidae) and four other scorpions with captured prey (2 moths, 1 *Clubiona* sp.

Figure 2.—"Sit and wait" foraging of *Bnthns* cf. *occitanus* on a shrub, *Helianthemnm sqnamatnm*.

epiphytic spider, 1 *B.* cf. *occitanns* scorpion) on shrub branches, while we only observed one scorpion unsuccessfully attacking a moth and one scorpion with a captured *Dicranocephalns* sp. (Heteroptera: Stenocephalidae) on the ground.

Our data showed that climbing behavior of *B.* cf. *occitanus* was related to scorpion size, small individuals having a higher probability of climbing on shrubs than larger scorpions. The higher proportion of juveniles than adults on vegetation has been previously indicated for both *B. occitanns* (Skutelsky 1996) and other scorpion species (Polis 1990; Brown & O'Connell 2000). Because the climbing behavior of *B. occitanns* is related to scorpion size, the proportion of individuals foraging on shrubs may vary seasonally due to phenological changes

Table 1.—Shrub selectivity (Savage's index, W_i) by *Bnthns* cf. *occitanns.* * Significant positive selection (P < 0,05, χ^2 test after sequential Bonferroni correction).

Shrub	% used	% available	W_i	S.E. (W_i)	χ^2
Artemisia spp.	19.51	29.59	0.66	0.32	1.11
Gypsophila strnthinm	2.44	0.46	**5.36***	1.14	14.54
Helianthemnm violacenm	2.44	1.21	2.01	1.05	0.93
Helianthemnm sqnamatnm	17.07	21.24	0.80	0.35	0.31
Lepidinm snbnlatnm	14.63	7.13	**2.05***	0.40	6.82
Ligenm spartnm	7.32	8.65	0.85	0.57	0.07
Ononis tridentata	2.44	0.15	**16.08***	1.40	115.21
Retama sphaerocarpa	12.20	0.30	**40.20***	0.82	2279.72
Salsola vermicnlata	4.88	7.13	0.68	0.70	0.20
Stipa spp.	4.88	4.40	1.11	0.71	0.02
Thymus zygis	12.20	19.73	0.62	0.43	0.80

in the age (and size) structure of scorpion populations (e.g., Warburg & Polis 1991; Brown & O'Connell 2000).

Foraging by scorpions on shrubs has been explained as a behavior to avoid predation, especially by other scorpions (Polis 1980; Polis & McCormick 1987), and also to exploit higher prey availability on plants than on the ground (Polis 1990; Skutelsky 1996; Brown & O'Connell 2000). On the one hand, our observations suggest that foraging on shrubs could be more profitable than on the ground. The fact that in the study site most arthropods on shrubs are much smaller (1.3 mg average dry weight) than on the ground (16.2 mg average dry weight: Sánchez-Piñero 1994) may be an important factor related to the higher frequency of small scorpions on shrubs. Also, previous studies of shrub canopy arthropods carried out in the study area by means of beating (Sánchez Piñero 1994; Sánchez-Piñero et al. unpublished data) allow us to hypothesize that selection of shrubs by scorpions is related to prey availability. Thus, available information showed that *Gypsophila struthium* and *Retama sphaerocarpa* had 4 and 2.5 times higher abundances of canopy arthropods, respectively, than most other shrubs in the study area. The fact that *R. sphaerocarpa* also exhibited very high densities of night-active insects during our *B.* cf. *occitanus* surveys also supports the idea that prey availability is related to shrub selection by the scorpions. *Lepidium subulatum* and *Ononis tridentata* were the only two flowering shrub species during our scorpion surveys, and we observed higher numbers of night-active insects (especially moths and homopterans flying near the flowers) in these plants than about other shrubs. The lack of significant selection for other shrubs may be related to their low canopy arthropod abundance in the study area (Sánchez-Piñero 1994).

Although we have observed three instances of *B. occitanus* capturing prey on shrubs, we do not know whether scorpions also climb onto shrubs to eat prey captured on the ground, as suggested for *Centruroides vittatus* (McReynolds 2008). Thus, foraging of *B. occitanus* on shrubs may be favored if this behavior not only allows access to shrub-inhabiting prey, but also reduces both inter- and intraspecific predation risks (Skutelsky 1996; Brown & O'Connell 2000; McReynolds 2008). More research will be necessary to evaluate whether prey availability is higher and risks of predation and cannibalism lower on shrubs than on the ground and to uncover the factors related to scorpion foraging on shrubs.

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